Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Safety Incident Report – 200403110

Final

Engine failure - Melbourne Airport, Victoria
25-Aug-2004
Boeing Company 777-312
9V-SYB

Australian Government

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Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

Published by: Australian Transport Safety Bureau
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ISBN and formal report title: see 'Document retrieval information' on page iv.

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DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
20043110	October 2006	149	1 921164 11 5

Publication title

Engine Failure – Melbourne Airport, 25 August 2004, Boeing Company 777-312, 9V-SYB

Prepared by

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www.atsb.gov.au

Acknowledgements

Singapore AAIB, UK AAIB, Singapore Airlines, SAESL, Rolls-Royce UK, Praxair

Abstract

At approximately 0104 Eastern Standard Time on 25 Aug 2004, the left engine surged during takeoff from Runway 34 at Melbourne Airport. The crew of the Singaporean registered Boeing 777-312 aircraft, 9V-SYB, subsequently reported that the surge occurred just at V_1. The crew elected to continue the takeoff and the left engine surged multiple times during the departure, until they shutdown the engine. Due to forecast turbulence, the crew maintained an altitude of approximately 3,000 ft above ground level to dump fuel and reduce the aircraft's weight for landing. Air Traffic Services vectored the aircraft over Port Phillip Bay for the fuel dump, which took approximately 1 hour, before the aircraft was returned to Melbourne for an uneventful single-engine landing. There were 300 persons on board and there were no reported injuries.

An examination of the engine found that several of the High Pressure Compressor (HPC) casing liners had eroded to the point of reducing the efficiency of the HPC.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations. Accordingly, the ATSB also conducts investigations and studies of the transport system to identify underlying factors and trends that have the potential to adversely affect safety.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and, where applicable, relevant international agreements. The object of a safety investigation is to determine the circumstances in order to prevent other similar events. The results of these determinations form the basis for safety action, including recommendations where necessary. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

It is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and findings. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. While the Bureau issues recommendations to regulatory authorities, industry, or other agencies in order to address safety issues, its preference is for organisations to make safety enhancements during the course of an investigation. The Bureau prefers to report positive safety action in its final reports rather than making formal recommendations. Recommendations may be issued in conjunction with ATSB reports or independently. A safety issue may lead to a number of similar recommendations, each issued to a different agency.

The ATSB does not have the resources to carry out a full cost-benefit analysis of each safety recommendation. The cost of a recommendation must be balanced against its benefits to safety, and transport safety involves the whole community. Such analysis is a matter for the body to which the recommendation is addressed (for example, the relevant regulatory authority in aviation, marine or rail in consultation with the industry).

EXECUTIVE SUMMARY

At approximately 0104 Eastern Standard Time on 25 Aug 2004, the left engine surged during takeoff from Runway 34 at Melbourne Airport. The crew of the Singaporean registered Boeing 777-312 aircraft, 9V-SYB, subsequently reported that the surge occurred just at V_1[1]. The crew elected to continue the takeoff and the left engine surged multiple times during the departure, until they shutdown the engine. Due to forecast turbulence, the crew maintained an altitude of approximately 3,000 ft above ground level to dump fuel and reduce the aircraft's weight for landing. Air Traffic Services vectored the aircraft over Port Phillip Bay for the fuel dump, which took approximately 1 hour, before the aircraft was returned to Melbourne for an uneventful single-engine landing. There were 300 persons on board and there were no reported injuries.

An examination of the engine found that several of the High Pressure Compressor (HPC) casing liners had eroded to the point of reducing the efficiency of the HPC.

As a result of the occurrence, the engine manufacturer has taken a number of steps to identify this failure mode during engine trend monitoring in order to reduce the likelihood of a recurrence.

1 V_1 is the take-off decision point at which, should the critical engine fail, the pilot can elect to abandon the takeoff.

FACTUAL INFORMATION

History of the flight

At approximately 0104 Eastern Standard Time, on 25 Aug 2004, the left engine surged during takeoff from Runway 34 at Melbourne Airport. The crew of the Singaporean registered Boeing 777-312 aircraft, 9V-SYB, subsequently reported that the surge occurred just at V_1[2]. The crew elected to continue the takeoff and the left engine surged multiple times during the departure, until they shutdown the engine. Melbourne Airport officers reported an amount of debris on Runway 34.

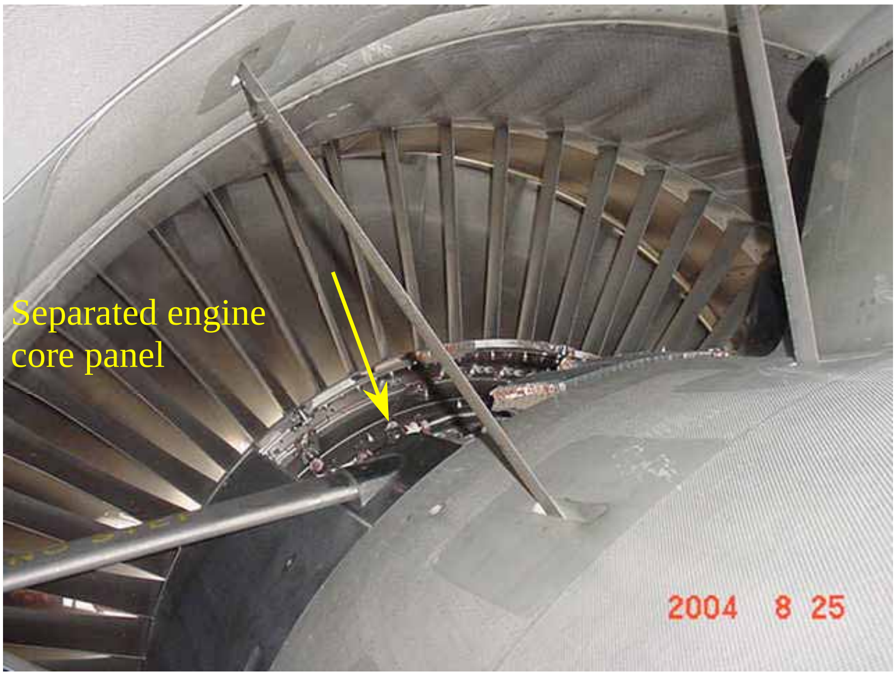
Due to forecast turbulence, the crew maintained an altitude of approximately 3,000 ft above ground level to dump fuel and reduce the aircraft weight for landing. Air Traffic Services vectored the aircraft over Port Phillip Bay for the fuel dump, which took approximately 1 hour before the aircraft was returned to Melbourne for an uneventful single-engine landing. There were 300 persons on board and there were no reported injuries.

The Australian Transport Safety Bureau (ATSB) dispatched an investigation team to Melbourne to examine the aircraft, where no obvious external damage was evident (Figure 1). The ATSB examination revealed that one of the left engine's composite core panels had broken and separated from the engine during the engine surge (Figure 2). The left engine, a Rolls-Royce Trent 800, Serial number 51067, exhibited only minor damage to a number of components. A borescope inspection of the engine compressor section revealed no significant anomalies with the engine compressor or turbine rotors or stators.

Figure 1: Trent 800 engine S/No. 51067 fitted to the left position of 9V-SYB

2 V_1 is the take-off decision point at which, should the critical engine fail, the pilot can elect to abandon the takeoff.

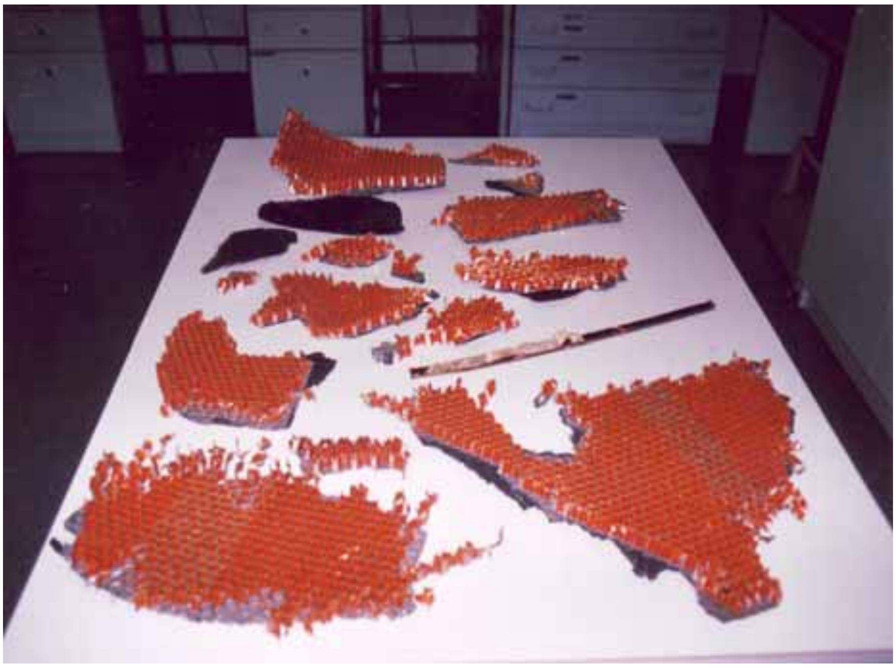
Figure 2: Separated composite engine core panel in cold stream duct



Damage to aircraft

An amount of debris was liberated from the separated left engine core composite panel and was recovered from the departure runway (Figure 3).

Figure 3: Composite panel remnants recovered from runway



Aircraft Information

Manufacturer	Boeing Company
Model	777-312
Serial number	28516
Registration	9V-SYB
Year of manufacture	1998

Left Engine Information

Manufacturer	Rolls-Royce Pty Ltd.
Model	Trent 800
Serial number	51067
Total time in service	15,614 Hrs
Cycles in service	4,527
Time since last repair	2,256 Hrs
Cycles since last repair	614
Date of last rework	Feb 2004
Date fitted to 9V-SYB	Feb 2004

Recorded Flight Information

The aircraft was fitted with both a solid state flight data recorder (FDR) and cockpit voice recorder (CVR). It was also equipped with an optical Quick Access Recorder (QAR). All recording devices were removed from the aircraft and forwarded to the ATSB to download the recorded information. The downloaded information was of good quality and indicated the following:

- During the takeoff roll, a loud bang was recorded on the CVR. This bang occurred 0.8 seconds before the automatic V_1 annunciation. Over the next 70 seconds, before the engine was shutdown, 57 bangs were audible on the CVR recording.
- At the time of the initial engine surge, the left engine N_1 values[3] decreased while the N_2 and N_3 values showed uncommanded increases.
- The maximum turbine gas temperature recorded for the left engine during the event was 910 degrees C.

A plot of the significant recorded left engine data is reproduced as Figure 15 on page 34 of Appendix A.

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3 N values refer to the compressor rotating speeds. N_1 represents the Low Pressure compressor, N_2 represents the Intermediate Pressure compressor and N_3 the High Pressure compressor.

Left engine examination

The left engine was shipped to a joint engine overhaul facility in Singapore for detailed examination, supervised by investigators from the ATSB and the Air Accident Investigation Bureau of Singapore.

The engine examination revealed that the high pressure compressor (HPC) casing abradable linings had deteriorated in service. There was a visible loss of abradable rotor lining on several of the HPC compressor casings (Figures 4 and 5). The engine manufacturer advised that the HPC stage-6 casing-to-rotor clearance was critical to engine airflow control at the take-off thrust setting.

Figure 4: HPC stage 6 casing and liner assembly

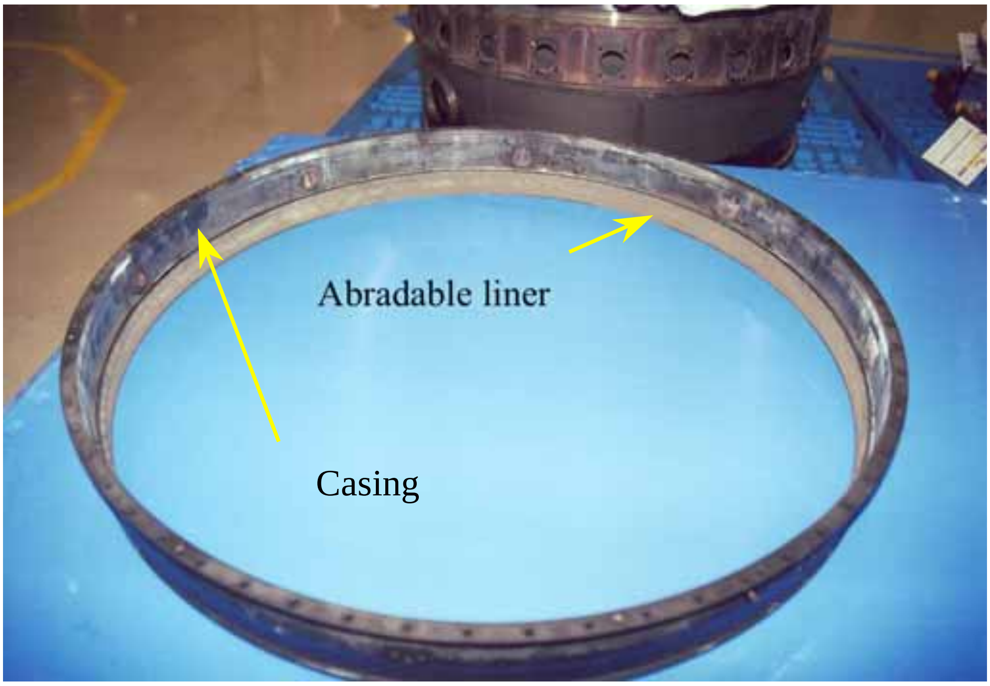
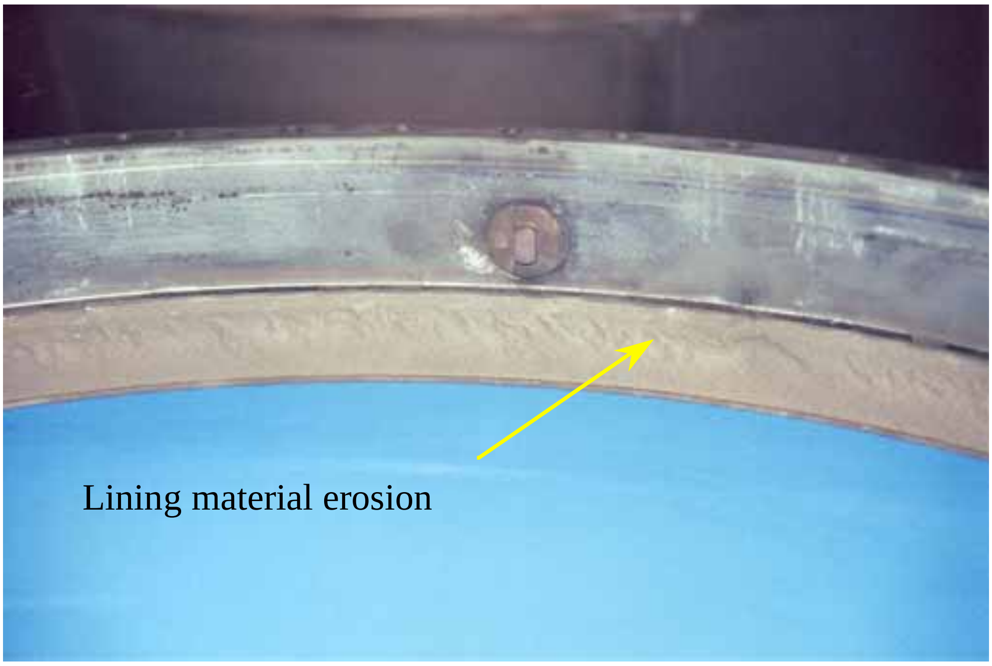


Figure 5: Detail of HPC stage 6 casing abradable liner erosion



Casing liner examination

All six HPC stage casings were sent to the engine manufacturer, Rolls-Royce in Derby, United Kingdom (UK), for examination, under the supervision of an investigator from the UK Air Accidents Investigation Branch. A copy of the detailed liner examination by Rolls-Royce is contained in Appendix A. The contractor responsible for the application of the lining material to a number of the casing liners, Praxair Surface Technologies, submitted a separate report to the ATSB based on their own examinations. A copy of that report is contained in Appendix B.

Engine health monitoring

Prior to this incident on 25 Aug 2004, the engine manufacturer had been monitoring the in-service health of Trent-800 engines. On 4 August 2004, an Engine Health Monitoring (EHM) alert was issued to the aircraft operator due to the identification of a step change in the engine's Turbine Gas Temperature (TGT) margin. As a result of this alert, the aircraft operator conducted the required engine inspection, including a borescope inspection of the HPC. Only minor damage, within acceptable limits, was noted to a small number of the stage-6 HPC blades, and the engine was returned to service. The borescope inspection only permitted limited examination of the HPC casing liner material in the immediate vicinity of the borescope inspection port.

Following this incident, the engine manufacturer conducted a review of other potentially affected engines with deteriorating HPC efficiency. That review found that two other Trent-800 engines exhibited performance degradation due to erosion of their HPC linings and both engines were removed from service.

Failed composite panel examination

An examination of the separated engine core composite panel indicated that all the panel fasteners were retained in their mounts after the panel failed (Figure 6). One fastener hole showed signs of wear, but there was no direct evidence to suggest that the fitting was loose at the time of the failure (Figure 7). It was apparent from wear in the fastener fitting that it may have been loose previously, and that this looseness may have contributed to some prior weakening of the panel structure, which contributed to the panel failure during the engine surge event.

Figure 6: Typical composite panel failure around mounting point

Figure 7: Elongated fastener hole showing signs of wear

ANALYSIS

The left engine surged at V_1 during takeoff from Melbourne Airport. The actions by the crew to continue the takeoff were appropriate for the circumstances and ensured a successful, single-engine, return to the airport.

The engine surge was as a direct result of a breakdown of the airflow within in the engine High Pressure Compressor (HPC). Directly contributing to that condition was a reduction in the HPC efficiency associated with the erosion and loss of HPC casing lining material, particularly at the rear stages of the HPC. The stage-6 lining material loss resulted in increased rotor tip clearances. The stage-6 lining material loss was the most critical stage for airflow control through the HPC during the takeoff.

The loss of HPC casing lining material was discussed in both the engine manufacturer and the sprayed coating contractors' reports (Appendixes A and B). As a result of the differing views presented in each report, the Australian Transport Safety Bureau (ATSB) conducted a review of both reports to determine the likely factors associated with lining material loss from the HPC casings. That review is included as Appendix C.

The ATSB review concluded that the coating quality issues were the most probable factor contributing to the premature degradation of the HPC casing lining leading to the engine surge. While acknowledging the possibility that oxidation may have weakened the coating particle cohesive strength, the significance of this effect had not been quantified in respect of the performance of the lining in service. Other proposed contributors such as Calcia-Magnesia-Aluminia-Silica (CMAS) ingestion, extended operation at elevated temperatures and the effects of thermal cycling were not substantiated by evidence. Similar casing liner issues were also apparent in all the other HPC casing liner stages in the engine.

If a step change was noted in the engine Turbine Gas Temperature (TGT) margin, the Engine Health Monitoring (EHM) program of the Trent-800 engines required a visual inspection of the HPC. However, this inspection was limited to examining the condition of the HPC compressor blades and was not capable of determining the extent of any deterioration of the HPC casing lining material.

The failed engine core composite panel was secondary to the engine surge event and did not contribute to the engine failure.

FINDINGS

Contributing factors

- The left engine surged during takeoff.
- The left engine High Pressure Compressor (HPC) casing liners exhibited lining material loss.
- The left engine HPC stage-6 casing lining material was eroded, increasing the rotor tip clearance and reducing the efficiency of the stage at take-off thrust.

Other safety factors

- The Engine Health Monitoring procedures detected the deterioration of the efficiency of the HPC, however the subsequent inspection requirements were unable to detect any deterioration of HPC lining material.

SAFETY ACTION

Engine manufacturer

As a result of this occurrence, the engine manufacturer, Rolls-Royce UK, advised the Australian Transport Safety Bureau that they have taken the following actions:

> Two engines that were identified as being at risk of surging due to degraded High Pressure Compressor (HPC) efficiency were removed from service.
>
> The Engine Health Monitoring (EHM) procedures have been changed. If an EHM alert is issued and troubleshooting reveals no findings to explain the observed change, the engine manufacturer will review engine parameter data in more detail. This may lead to a recommendation that the engine is removed from service.
>
> The aircraft maintenance manual will be updated to include an inspection check of the condition of the rotor path lining immediately adjacent to the borescope port hole and to contact the engine manufacturer if no evidence of lining loss.
>
> The engine manufacturer has also developed an algorithm to alert changes of HPC efficiency as part of the suite of automatically generated alerts produced for engine health monitoring purposes.